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Application of Near Field Communication for Health Monitoring in Daily Life

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Abstract— **We study the possibility of applying an emerging RFID-based communication technology, NFC (Near Field Communication), to health monitoring. We suggest that NFC is, compared to other competing technologies, a high-potential technology for short-range connectivity between health monitoring devices and mobile terminals. We propose practices to apply NFC to some health monitoring applications and study the benefits that are attainable with NFC. We compare NFC to other short-range communication technologies such as Bluetooth and IrDA, and study the possibility of improving the usability of health monitoring devices with NFC. We also introduce a research platform for technical evaluation, applicability study and application demonstrations of NFC.**

Keywords — Health monitoring, Mobile terminals, Near field communication (NFC), Short-range communication.

I. Introduction

As current health care systems are struggling with resource problems in many countries, self care patients are increasingly forced to manage their diseases themselves. For example, diabetes patients make most of their treatment decisions themselves (i.e., adjusting insulin levels according to their health status). Technology can play an important role in self care by providing accurate measurement devices, combining data from many sources, analyzing and providing reports on the data, and providing supervising healthcare specialists with systematically collected and analyzed information. This, however, requires technology to be easy-to-use, robust and maintenance-free.

Modern electrical health monitoring devices, such as scales, blood pressure monitors, blood glucose monitors or heart rate monitors, are relatively simple devices operated with normal batteries over periods of several months to several years, typically costing from tens to hundreds of euros. Typically, these devices are the stand-alone type with an on-board display and a reduced set of control buttons. Some of the high-end devices, such as those in [1] and [2], have on-board communication interfaces, either wired, such as RS-232 and USB, or wireless, such as Bluetooth and IR. The communication interfaces are needed for communication with a PC, which enables the systematic collection and analysis of data and possibly also networking with a backend system. The value of these is significant, especially in long-term health monitoring and in chronic disease management. From the usability point of view, wireless communication links are preferable to cables because they facilitate measurements at real-life settings. However, the drawbacks of traditional wireless technologies are their relatively high power consumption and vulnerability to eavesdropping.

From a marketing point of view, future devices with communication capabilities should not be more expensive, more complex to use, or provide significantly shorter operation time than those available now. Hence, current state-of-the-art standard short-range wireless communication technologies, such as Bluetooth and IrDA, are suboptimal and not competitive solutions for health monitoring devices. The price of Bluetooth per node is several dollars, which is too much for many simple devices. The power consumption of Bluetooth, typically tens of milliwatts, is too much for the continuous long-term operation of battery-operated devices. Associating two Bluetooth devices together takes typically several tens of seconds, and re-connecting previously paired devices often requires manual intervention. The problems pertaining to the power consumption and cumbersome association of the communicating devices can be resolved by replacing the wireless communication by cables, but the cables are not feasible in everyday life: they are often missing when needed, they wear out in use, they get unhygienic over time, and they are cumbersome in connection.

In March 2004, a new interconnection technology, Near Field Communication (NFC), was launched by Sony, Philips and Nokia, by the establishment of the NFC Forum [3]. The NFC Forum is a non-profit industry association for advancing the use of NFC short-range wireless interaction in consumer electronics, mobile devices and PCs. The NFC Forum will promote the implementation and standardization of NFC technology to ensure interoperability between devices and services. As of the beginning of 2006, over 50 members have joined the NFC Forum. We expect NFC technology to provide a potential solution for the above-mentioned problems in many health monitoring applications, since it is less complex and thus cheaper, as well as having lower power consumption and better usability than the alternative technologies. NFC supports the use of mobile terminals by the TouchMe interaction paradigm, which is an

intuitive and user-friendly way of establishing connections and exchanging information between mobile terminals and other devices or objects [4].

In this paper, we suggest that NFC is, compared to other competing technologies, a high-potential technology for short-range connectivity between health monitoring devices and mobile terminals. We propose practices to apply NFC to some health monitoring applications and study the benefits that are attainable by NFC. We compare NFC to other short-range communication technologies such as Bluetooth and IrDA, and study the possibility of improving the usability of health monitoring devices using NFC. We also introduce a research platform for technical evaluation, applicability study and application demonstrations of NFC.

II. NEAR FIELD COMMUNICATION (NFC)

Near field communication (NFC) is a new, very short-range (max. 20 cm), wireless point-to-point interconnection technology, evolved from a combination of earlier RFID contactless identification and interconnection technologies (ISO14443A/MIFARE/FeliCa). It enables users of handheld electronic devices to access content and services in an intuitive way by simply “touching” smart objects, that is connecting devices just by holding them next to each other. The communication is based on inductive coupling. The 13.56 MHz carrier frequency is used and the maximum data rate is 424 kbps.

The heritage of earlier standards gives NFC compatibility benefits with existing RFID applications, such as access control or public transport ticketing – it is often possible to operate with old infrastructure, even if the RFID card is replaced with an NFC-enabled mobile phone, for example. This is possible because of NFC’s capability to emulate RFID tags (“card interface mode”). NFC hardware can include a secure element for improved security in critical applications such as payments. For example, a credit card could be integrated into a mobile phone and used over NFC.

NFCIP-1 is an NFC-specific communication mode, defined in the ECMA-340 standard. This mode is intended for peer-to-peer data communication between devices. In this mode, NFC is comparable to other short-range communication technologies such as IrDA, although the physical data transfer mechanism is different. The NFCIP-1 mode is divided into two variants: active mode and passive mode. In active mode, both participants generate their own carrier while transmitting data. In passive mode, only the initiator generates a carrier during communications, and the target device uses load modulation when communicating back to the initiator, in a way similar to passive RFID tag behavior [5]. This makes it possible to save power in the target device, which is a useful feature if the target device has a very restricted energy source, such as a small battery. It is possible to make a target device – such as a sensor readable over NFC – last for several years, even if operated from a small lithium coin-cell battery.

NFCIP-2 (specified in ECMA-352) defines how to automatically select the correct operation mode when starting communications. This and related standards are shown in Fig. 1 [6].

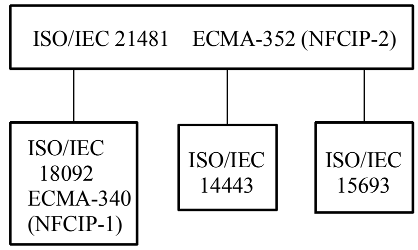

Fig. 1. NFC-related standards. The upper layer defines the mechanism of selecting the communication mode on the lower layer.

NFC is a standard technology backed by the leading mobile phone manufacturers. Thus, its deployment will be strongly driven via its integration into cellular handsets. A forecast by ABI Research of NFC-enabled phone shipments during the next few years is shown in Fig. 2 [7].

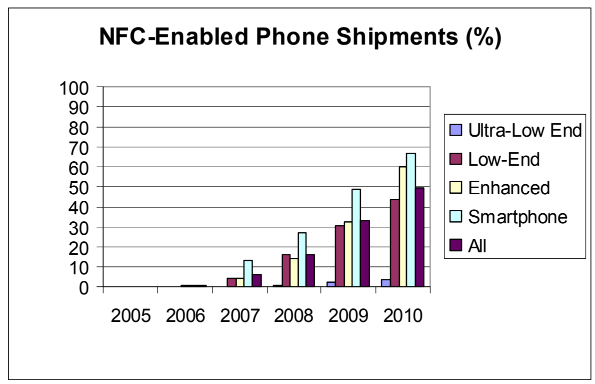

Fig. 2. A forecast of NFC-enabled phone shipments.

III. APPLICATIONS

The first commercial applications of NFC have been based on activating existing mobile phone functions and services, such as calls, SMS messages and browsing, by touching a service shortcut RFID tag that stores a fixed data record [8]. However, the repertoire of potential NFC applications is much more versatile, ranging from connectivity between devices and objects to various ticketing, payment and access control applications [7]. The focus of this paper is on applying NFC to health monitoring applications as an easy to use, low-power and low-cost wireless interface for medical sensors and instruments such as blood pressure monitors, blood glucose monitors, heart rate monitors and personal weight scales, and facilitating the use of mobile terminals as a patient's user interface, as well as a gateway to the backend system.

Our reference system architecture is illustrated in Fig. 3. The proposed architecture integrates NFC into health monitoring devices and mobile terminals, enabling TouchMe-based interaction with health monitoring devices,

which is possible even through clothing. Touching can trigger a data transfer operation between the devices via NFC. Touching can also establish a connection between devices using other wireless technologies, such as Bluetooth. In addition to connectivity between devices, touching can trigger predefined functions of the health monitoring devices, such as on-off switching or labeling measurement-related events during the measurement period. From the usability viewpoint, the touching point of the devices should be indicated illustratively and in a standard way, so that users can envisage the usage of NFC and the functionality to be triggered by touching. In addition, the user has to be provided with a clear feedback such as some acoustic signal.

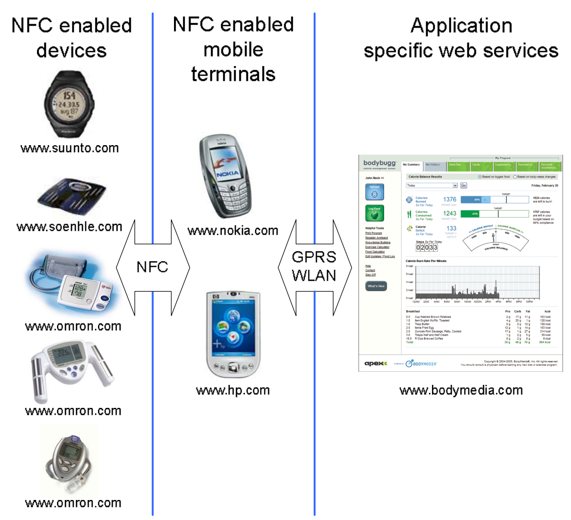

Fig. 3. Measurement results and configuration parameters can be easily transferred between NFC-enabled measurement and terminal devices. Measurement results can be saved in the terminal or transmitted over the internet to a web-service. Note that the products in the figure are examples and do not currently contain NFC.

To analyze the requirements of the communication technology of health monitoring devices, we divide their applications into three main categories:

1) *Real-time patient monitoring* that requires continuous uninterrupted connection of the health monitoring device to the mobile terminal of the patient, and/or to the backend system without patient activity. A typical example of this is ECG telemonitoring over the phone in the case of sudden heart disease symptoms.
2) *Off-line health monitoring*, in which the health data (e.g. EGC, heart rate) is monitored continuously during a certain period (e.g. 24h Holter ECG, or exercise heart rate recording) and stored in the memory of the monitoring device, from which the data is transferred to the mobile terminal and/or to the backend system after the monitoring period.
3) *Health or disease management*, in which monitoring is based on sparse measurements (e.g. blood pressure, blood glucose, or weight), the amount of data is limited, and readings may be transferred to the mobile terminal or back-end immediately, or later on in blocks of several readings acquired over time. A typical example is diabetes management.

In the following sections, two case applications are described more in detail:

--Off-line type heart rate monitoring.

--Weight and blood pressure management by sparse measurements.

A. Heart Rate Monitoring

Heart rate monitoring is commonly used and well known in health care and in physical exercise. Continuous long-term heart rate monitoring can even be used in the diagnosis of medical conditions such as heart disease and stress management. In most cases, measurements can be implemented off-line, after which the data is transferred to the terminal, analyzed and visualized for the user. For example, Polar has created a running/cycling computer concept where the S625X heart rate monitor can measure several parameters of exercise and save them as a file [9]. The saved file can be transferred off-line, using an IrDA link to the Nokia 5140i, or through a PC connection to the Polar personal trainer web-service [10] or Polar PC software. This kind of concept is also useful in the case of chronic disease management or self-rehabilitation applications in health care.

High-end heart rate monitors can store the beat-to-beat heart rate for tens of hours. This information is not utilized efficiently enough by many users, mostly because of cumbersome data transfer from the monitor to a PC or a mobile terminal. Providing the heart rate monitors with NFC communication would be an ideal solution. The data could be transferred to a PC or mobile terminal simply by touching them with the heart rate monitor.

B. Weight, glucose and blood pressure management

Weight, glucose and blood pressure measurements are typical sparse measurements in health management. For long-term monitoring purposes, the measurement results are often documented manually. Easy electrical measurement, data management and visualization motivate patients to watch and control their own situation. It also enables fluent cooperation between patients and supervising medical specialists.

Nowadays very few consumer weight scales and blood pressure monitors are equipped with data transfer capabilities. Instead, many devices have an internal memory for storing measurement results. The problem with internal memory is that in many families the devices are used by many persons. Afterwards it is not possible to know to whom each result belongs. Multi-user user interfaces also tend to be more difficult to use. Separate measurement devices also contain their own measurement history, so that the user's measurement history is spread over many places. These problems make data collection and analysis very troublesome. NFC can help in this problem by allowing each user to transfer his measurement result to his/her mobile

terminal immediately after the measurement. The mobile terminal can store enough results for a detailed analysis and also visualize the data for the user. The same health application can contain measurements from different sources and illustrate them in the same user interface. The measured data can also be easily sent to the back-end information system for medical use (e.g. a supervising doctor).

IV. NFC APPLICABILITY

NFC is especially applicable to off-line health monitoring, such as the heart rate monitoring case in section 3A, as well as health or disease management with sparse measurements, such as the weight, glucose and blood pressure management case in section 3B. The short communication range of NFC limits its applicability in real-time patient monitoring that requires continuous connectivity of the health monitoring device without patient's activity.

From the techno-economic viewpoint, the advantages of NFC over alternative wireless communication technologies such as Bluetooth and IrDA are its lower price, lower power consumption and better immunity to eavesdropping.

NFC can potentially improve the usability of many health monitoring devices:

1) It allows easy-to-use low-power communication based on the TouchMe paradigm, and has a short latency time compared to plugging in cables or establishing a Bluetooth connection with a mobile terminal. In sparse measurements (such as weight), the user can pick up and store his measurement result with a personal mobile terminal immediately.
2) In real-time monitoring or more data-intensive applications, it can be used for easily establishing a Bluetooth connection between two devices by bringing them close to each other. The user doesn't have to find the correct menu items and configuration parameters.
3) Due to the extremely low power consumption of the target device in NFCIP-1 mode, it can be used for the on-off switching and triggering other predefined functions of a health monitoring device by bringing another NFC-enabled device close to it. This can be done even through clothing.

For further technical evaluation and applicability studies, we have built a platform that enables NFC connectivity of health monitoring and other instruments. The key component of the platform is the Intelligent Interfacing Module for Smart Objects that incorporates NFC, Bluetooth and IrDA for short-range connectivity, a microcontroller, a real-time clock circuit and data memory for on-board data processing, and various interfaces for wired connections to health monitoring devices. We have carried out preliminary tests by reading measurement results from temperature sensors and weight scales on the display of an NFC-enabled mobile phone. The latency between touching the device and displaying the result has typically been below one second in our tests.

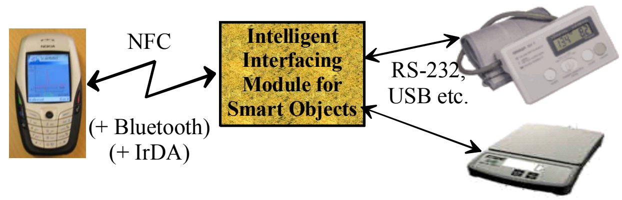

Fig. 4. Platform for technical evaluation and applicability studies of NFC.

V. CONCLUSIONS AND FURTHER WORK

We conclude that NFC well suits off-line health monitoring applications such as the heart rate monitoring case in section 3A, as well as health or disease management with sparse measurements, such as the weight and blood pressure management case in section 3B. The short communication range of NFC limits its applicability in real-time patient monitoring applications that require continuous connectivity of the health monitoring device without patient activity. From the techno-economic viewpoint, the advantages of NFC over alternative wireless communication technologies such as Bluetooth and IrDA are its lower price, lower power consumption and better immunity to eavesdropping. NFC can improve the usability of many health monitoring devices by enabling data transfer and the activation of predefined functions by touching them by an NFC-enabled mobile terminal or other handheld device. After NFC has broken through in mobile terminals, it will also easily be taken into use in health monitoring devices.

We will continue our work through further technical evaluations, applicability studies and demonstrations based on our NFC platform depicted in Fig. 4.

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